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Major Article

Assessment of terminal cleaning in pediatric isolation rooms: Options for low-resource settings

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Patient isolation
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Background: Few studies have evaluated terminal cleaning in low-resource settings.
Methods: Adequacy of pediatric isolation room terminal cleaning was evaluated using quantitative bacterial surface cultures, ATP bioluminescence assays, and fluorescent high-touch surface markers at Tygerberg Children's Hospital in South Africa (August 1, 2014-October 31, 2015). Cleaning adequacy was assessed by comparing pre- and postcleaning measurements. Influence of verbal feedback was determined by comparing cleaners' first and subsequent cleaning episodes. Cleaning methods were compared for cost, time, and feasibility.
Results: Adequacy of terminal cleaning was evaluated in 25 isolation rooms after hospitalization for pulmonary tuberculosis (n = 13), respiratory (n = 5) and enteric viruses (n = 5), pertussis (n = 1), and methicillin-resistant *Staphylococcus aureus* (n = 1). Mean aerobic colony counts and mean ATP relative light units declined between pre- and postcleaning evaluations (39 ± 41 to 15 ± 30 [$P < .001$] and 72 ± 40 to 23 ± 11 [$P < .001$]). Fluorescent marker removal was initially poor, but improved significantly at subsequent cleaning episodes (17 out of 78 [22%] to 121 out of 198 [61%]; $P < .001$); mean aerobic colony counts and ATP values also declined significantly following feedback. Cost, time, and resources required for ATP and surface cultures far exceeded that required for fluorescent markers.
Conclusions: Adequacy of isolation room cleaning improved following feedback to cleaning staff. Fluorescent markers are an inexpensive option for cleaning evaluation and training in low-resource settings.

BACKGROUND

Health care facilities in low-middle income countries (LMICs) are challenged by a large infectious disease burden, insufficient infrastructure, and limited infection prevention (IP) resources.[1] In particular, hospital isolation facilities are severely limited, impeding implementation of patient isolation for containment of *Mycobacterium tuberculosis* (TB), multidrug-resistant bacteria, and viruses.[2] Pathogen contamination of the near-patient environment (ie, surfaces and equipment) occurs by shedding of bacteria-laden skin cells and settling of exhaled droplet nuclei on surfaces. Pathogens are then transmitted by indirect transfer on health care workers' hands or shared equipment, or via direct contact by the next room occupant.[3] Experimental studies modeling pathogen transmission routes show rapid contamination of clinical environments through direct and indirect contact. In a study using plant DNA as a marker of contamination, spread from a single contaminated point source (a telephone handle) was confirmed to all clinical areas on a neonatal intensive care unit within 4 hours.[4]

Pathogen transmission from infected or colonized patients establishes an environmental reservoir of bacteria, viruses, and spores that remains a potential source of infection even after the affected patient is discharged.[5] Prolonged survival of multidrug-resistant (MDR) bacteria and spores in hospital environments is well described; viable *Acinetobacter*, *Pseudomonas*, *Klebsiella*, *Enterococcus,* and *Staphylococcus aureus* species have been isolated from dry hospital surfaces at up to 12-30 months.[5,6] Persistence of these pathogens in the hospital environment is particularly concerning for LMIC and other settings where environmental cleaning is suboptimal and/or nonstandardized.[7-9]

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Renewed interest in environmental cleaning for health care-associated infection (HAI) prevention has been generated by studies linking nosocomial infection risk to contamination of patient environments.[10-13] The role of a contaminated hospital environment in pathogen acquisition has been established through prior room occupancy studies. Isolation of the same pathogen from a prior room occupant and a new patient (with no epidemiologic link) implicates the near-patient environment as an important source for pathogen transmission. Next room occupants have an estimated 1.5-4.5 fold increased risk of acquiring a bacterial pathogen that caused infection in the prior room occupant[7,14,15] This mode of infection has been demonstrated for a variety of organisms, including *Clostridium difficile*,[15] methicillin-resistant *S aureus* (MRSA),[16] and multidrug-resistant gram-negative bacilli.[17] Further compelling evidence for the role of the hospital environment in infection transmission is reduced HAI incidence when frequency and/or adequacy of environmental cleaning is increased.[7,18,19] Enhanced environmental cleaning is also frequently implemented as part of a multimodal outbreak control intervention, highlighting the hospital environment as a reservoir for pathogen persistence.[5,11]

Given the elevated risk for HAI with suboptimal environmental cleaning, effective and evidence-based guidelines for terminal or postdischarge cleaning of isolation facilities are needed. Although widely available and implemented in high-income settings,[20-22] standard and terminal cleaning guidelines are lacking in many resource-constrained hospitals. A further challenge is the lack of standardized definitions and methods to determine whether surfaces are in fact clean, because visual assessment of cleanliness does not correlate with microbiologic evidence of reduced contamination.[23]

Environmental surface cultures, fluorescent marker removal,[23,24] and ATP bioluminescence assays[25,26] are the most commonly employed cleaning evaluation methods in high-income settings.[7,27] Data on adequacy of terminal cleaning in low-resource health care facilities is lacking, with no guidance for suitable and cost-effective cleaning evaluation methods. We conducted a multimodal evaluation of isolation room terminal cleaning and measured influence of verbal feedback to cleaners on the adequacy of terminal cleaning at a pediatric referral hospital in Cape Town, South Africa.

METHODS

Setting

The Tygerberg Children's Hospital (TCH) has 300 pediatric beds within a large (1,384-bed) academic hospital complex. Sick neonates, infants, and children (aged 0-14 years) are admitted to 13 neonatal and pediatric wards (including surgical, medical generalist, specialty, and intensive care facilities). The burden of infectious diseases is high, with HIV and TB disease, lower respiratory tract infections, gastroenteritis, and bacterial infections predominating. Among pediatric bloodstream infection (BSI) isolates, gram-negative pathogens predominate and overall rates of antimicrobial resistance are high. Among hospital-acquired BSI pathogens, 78% of *Klebsiella pneumoniae* are extended spectrum β-lactamase producers, 22% of *Esherichia coli* produce extended spectrum β-lactamase, 72% of *Acinetobacter baumannii* exhibit MDR, and 65% of *S aureus* are methicillin-resistant.[28] Among children isolated for culture-confirmed TB, drug-resistant isolates are common (20% MDR, 2% extensively drug-resistant, and 4% rifampicin monoresistant).[29] Five pediatric wards have 18 single rooms available for patient isolation (50% with negative pressure ventilation), with priority given to patients requiring airborne or droplet precautions. Isolation bed demand[29] is high, especially in winter, with staff required to rapidly turn over rooms for admission of new patients requiring isolation. Each ward averages 28 beds serviced by 1 permanent cleaning staff member, under direct supervision of the ward nursing managers.

Terminal cleaning

Indications for isolation room terminal cleaning (after patient discharge) include any patient isolated under transmission-based precautions; for example, airborne (TB), droplet (respiratory and gastrointestinal viruses), and contact (MDR bacterial infections).[2] The hospital's unit for infection prevention and control gives annual training in cleaning methods, but without routine evaluation of terminal cleaning adequacy. The recommended method for terminal cleaning at our institution includes disposal of all nonfixed items followed by cleaning of surfaces and furniture with water and detergent. Once dry, surfaces are wiped with disinfectant (usually 70% alcohol; sodium hypochlorite is only used for patients with *Clostridium difficile* infection).

Study design

Contamination of pediatric isolation rooms on patient discharge was evaluated (before and after terminal cleaning) between August 1, 2014, and October 31, 2015. Three methods were used: fluorescent markers, ATP bioluminescence assays (CleanTrace swabs and a portable luminometer from 3M Health Care), and bacterial surface cultures. Adequacy of cleaning was established by comparing pre- and postcleaning measurements for each room. Following first measurement of cleaning adequacy, each cleaner received individual verbal feedback. The influence of verbal feedback to cleaners was determined through comparison of measurements for cleaners' first and subsequent cleaning episodes (each cleaner was assigned a unique code). The cost (including consumables and labor), time, and equipment required for each cleaning evaluation method was documented.

Sample collection

Surface swabs (using a cotton swab premoistened with sterile water) were collected from 5 surfaces (ie, bedrail, bedside table, sink, door handle, and mattress) before and after terminal cleaning. ATP relative light unit (RLU) readings were measured on 4 surfaces (ie, bedrail, bedside table, sink, and mattress) using CleanTrace swabs before and after terminal cleaning. For this study, surfaces measuring <100 RLU were considered clean, although there is considerable disagreement in published literature regarding cutoffs for cleanliness.[27] We applied the ultraviolet (UV) disclosing lotion GlitterBug Potion (Brevis Corp, Salt Lake City, UT) to flat surfaces using a cotton bud in a circular motion, creating a UV marker diameter of approximately 3 cm. Between 10 and 13 fluorescent marks were placed on high-touch surfaces in each room before cleaning (eg, bedrail, bedside table, sink tap, light switch, and door handle); the proportion of marks removed postcleaning was recorded.

Laboratory methods for surface cultures

Cotton swabs premoistened with sterile water were used to sample a prestandardized area of the bedrail, bedside table, sink, door handle, and mattress. In the laboratory, swabs were immersed in 1 ml sterile water and vortexed for 30 seconds; a new sterile swab was used to inoculate a blood agar plate that was incubated at 37°C for 48 hours. Aerobic colony count (ACC) was recorded for each plate and each unique colony was Gram stained. Gram-positive cocci were identified as being *S aureus*, coagulase-negative staphylococci, enterococci, or streptococci through catalase testing, pyrrolidonyl aminopeptidase activity, and/or latex